ERIM
FORMERLY WILLOW RUN LABORATORIES, THE UNIVERSITY OF MICHIGAN

WHEAT PRODUCTIVITY ESTIMATES USING LANDSAT DATA
TYPE II PROGRESS REPORT

for the period

16 November 1975 - 15 February 1976

114800-12-L

NASA Contract No. NAS5-22389

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The following report serves as the third Type II progress report for LANDSAT Follow-on Investigation #2062L which is entitled, "Wheat Productivity Estimates Using LANDSAT Data."

This investigation has two primary objectives. These objectives are:

1. to develop techniques and procedures for estimating characteristics of wheat canopies which are correlated with potential wheat grain yield (e.g., leaf area index [L.A.I.], percent vegetation cover, or dry weight biomass) by use of LANDSAT data.

2. to demonstrate the usefulness of LANDSAT data for estimation of wheat yield on a LACIE (Large Area Crop Inventory Experiment) intensive test site.

A. PROBLEMS

We have so far not received aerial photographs obtained over the Finney site, or field reflectance data obtained by the helicopter and by the van. Although the project can continue without this data, it would be highly desirable to have it. Also, the 3 May LANDSAT data over Finney which we expected to use, and for which LANDSAT imagery provided by USDA showed no problems, is apparently not available from NASA, due to a non-recoverable problem with the original data tape at Goddard Space Flight Center. This limits the utility of the Finney site in performing desirable temporal studies. However, we have requested that NASA/JSC provide aircraft scanner data (MSDS) for the

April-May 1975 period gathered over the Finney site, have ordered LANDSAT data for two early spring passes (March and April of 1975) which might prove to be of value, and we are presently proceeding by using available data from several Ellis LANDSAT passes.

B. ACCOMPLISHMENTS

Processing of LANDSAT data has begun for data collected November 22, 1974, and May 21 and June 18, 1975 covering Finney County. The 21 May data has been made ready for use, with the data reformatted and current-year field boundaries (polygons) prepared. The other two sites are nearly ready.

We have recently received from Johnson Space Center some yield information for the 1974-1975 wheat growing season for the Ellis intensive test site. Accordingly, we have begun to prepare Ellis LANDSAT data for use, including 6 dates scattered through the growing season. The 6 dates are: 16 October 1974, 3 May 1975, 11 May 1975, 21 May 1975, 7 June 1975, and 17 June 1975. These tapes have been reformatted, and we are in the process of defining the field designations (polygons) for the pertinent fields for each time period. This set of data is expected to give a more complete temporal yield analysis than is possible for the Finney site with its limited available LANDSAT coverage.

For the 21 May Finney site, signatures have been computed for fields for which we have ancillary ground data. This was done using the procedure [1] of a 1.5 pixel inset to insure that all pixels examined would be, without question, interior to the field and not include field boundaries and portions of adjacent fields. The inset, and the narrow dimension or small overall size of some of the fields prevented a statistically valid signature (which requires a minimum of 4 pixels) from being computed for three of these fields.

In order to analyze multitemporal data sets, it is desirable for data in one time period to correspond to the data in another, such

that for targets with the same reflectance, both time periods would use the same data values. In this regard, we are considering the alternatives of using a signature extension technique such as CROP-A [2], or testing a "haze-correction" algorithm now under development [3], or using some other procedure.

In addition to the above efforts, we have continued to reduce harvested field samples to leaf area index and photographic data to percent cover.

C. RESULTS

The hypotheses which are the foundation of this project are the following:

(1) Field condition (percent cover, LAI) can be inferred by use of LANDSAT data;

(2) Field condition (at a point in time, and over time) is indicative of eventual wheat grain yield; and

(3) Therefore LANDSAT data can be used to infer wheat grain yield.

These hypotheses are partially based on previous theoretical work which was carried out under NASA Contract NAS9-14123 [4].

The field data collection and the subsequent reduction of the field data to relevant indicators of field condition (percent cover, LAI), together with the processing of LANDSAT data from 21 May 1975, now permit us to address the validity of these hypotheses.

Figures 1 thru 4 show relationships between LANDSAT data and field condition for the eight fields for which we have all of the following:

(1) Valid LANDSAT signatures (formed from more than 4 pixels);

(2) Harvested wheat LAI data;

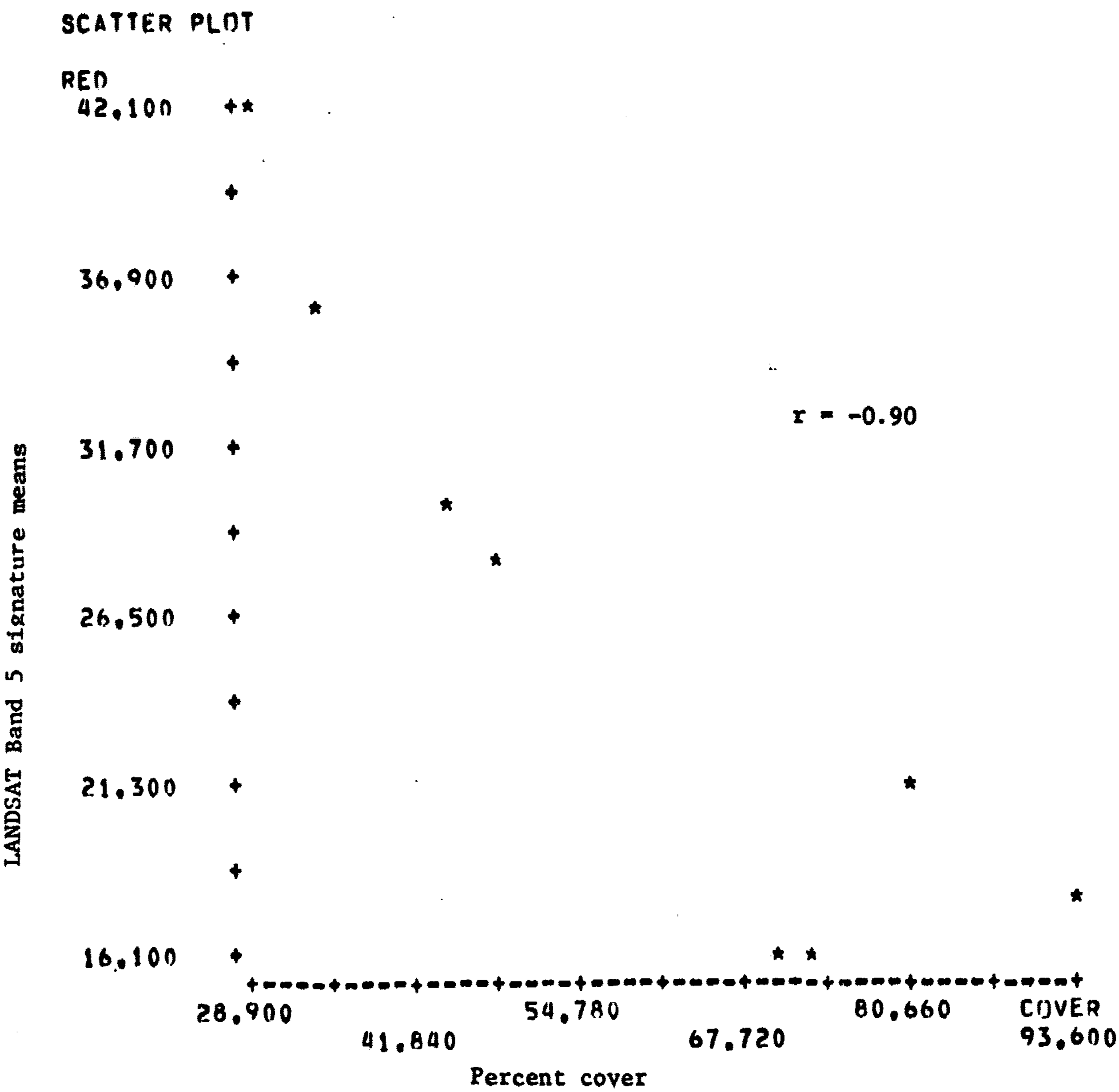

FIGURE 1. SCATTER PLOT OF SIGNATURE MEANS IN LANDSAT BAND 5 (RED BAND) VS. ESTIMATES OF PERCENT GREEN VEGETATION COVER DERIVED FROM ERIM FIELD PHOTOGRAPHS

FINNEY COUNTY SITE, 21 MAY 1975

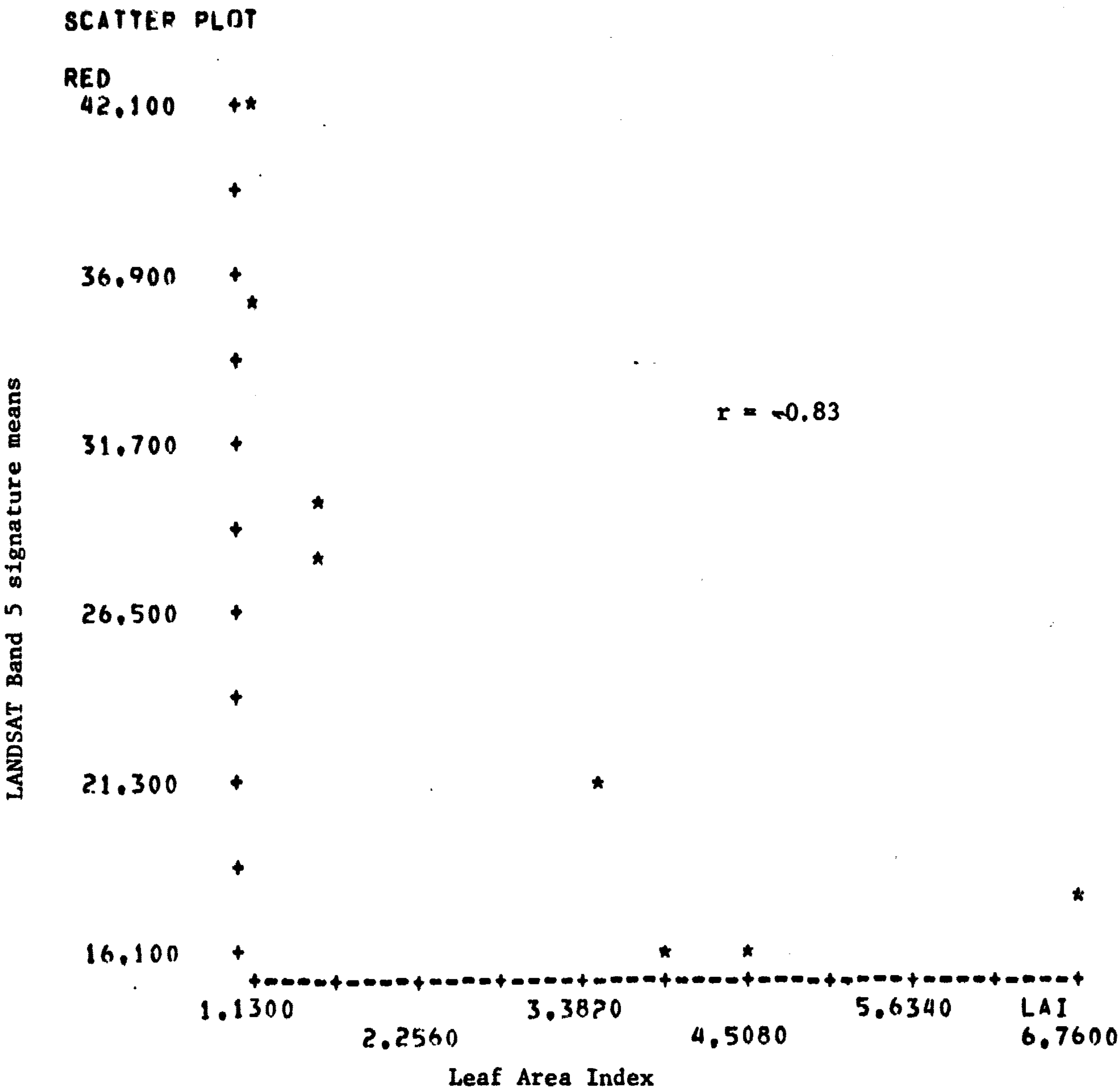

FIGURE 2. SCATTER PLOT OF LANDSAT BAND 5 VS. ESTIMATES OF GREEN LEAF AREA INDEX DERIVED FROM ERIM HARVESTED WHEAT SAMPLES

FINNEY COUNTY SITE, 21 MAY 1975

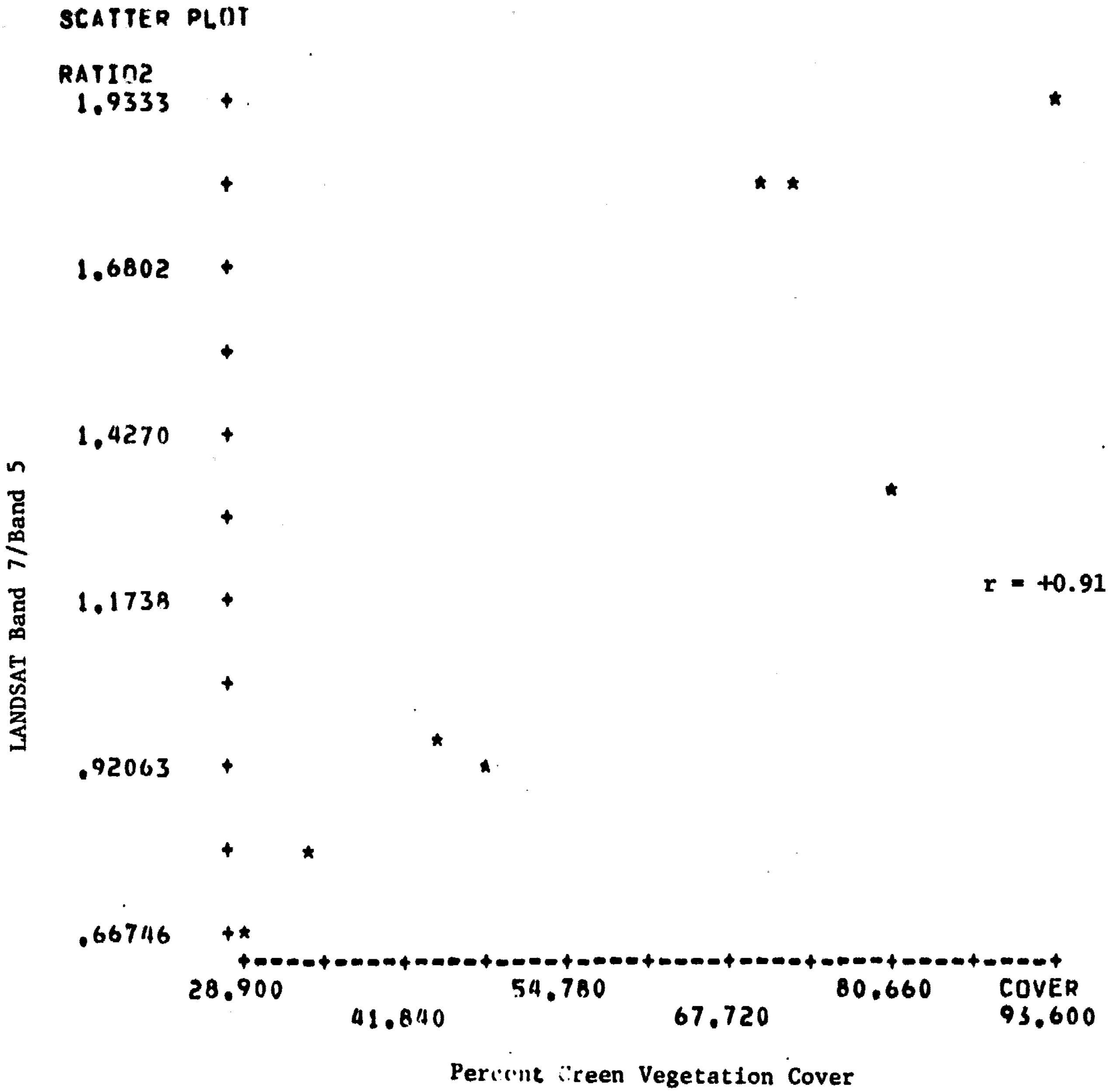

FIGURE 3. SCATTER PLOT OF A RATIO OF LANDSAT BANDS 7 AND 5 VS. ESTIMATES OF PERCENT GREEN VEGETATION COVER DERIVED FROM ERIM FIELD PHOTOGRAPHS

FINNEY COUNTY SITE, 21 MAY 1975

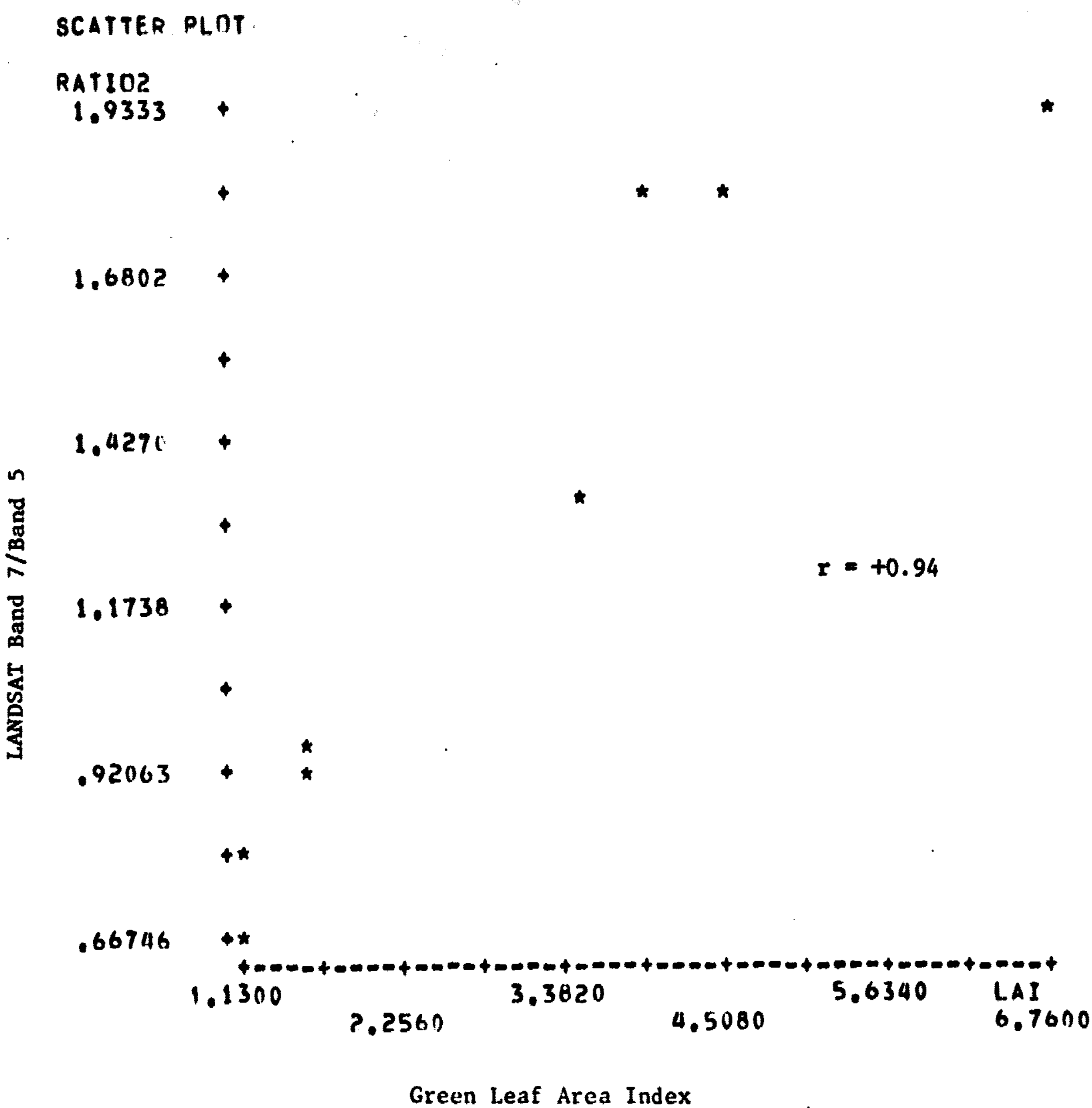

FIGURE 4. SCATTER PLOT OF RATIO OF LANDSAT BANDS 7 and 5 VS. GREEN LEAF AREA INDEX DERIVED FROM ERIM HARVESTED WHEAT SAMPLES

FINNEY COUNTY SITE, 21 MAY 1975

(3) Photographically determined percentage of green vegetation cover data; and

(4) Harvested grain yield data.

In all four figures presented there is a significant correlation between the LANDSAT data and field condition. Note, however, especially in Figures 1 and 2, that there is greater sensitivity of LANDSAT data to changes in vegetation cover and LAI at low values of vegetation cover and leaf area index than at high values of these parameters. This situation is what we expect based on previous work with data other than LANDSAT data [5].

Figures 5 and 6 show the relationship between field condition as of 21 May 1975 (heading) and eventual harvested wheat grain yield. It appears as though yield is much more sensitive to differences in field condition at low values of vegetation cover and leaf area index than at high values of these parameters.

Figures 7 and 8 show the relationship between 21 May LANDSAT data and harvested grain yield. The relationship has the highest correlation for the fields with low values of yield, which are also the fields with low vegetation cover and leaf area index. The reason for this is probably the somewhat poorer correlation between field condition and yield at high values of these parameters, and the concomitant generally poorer correlation between LANDSAT data and field condition at high values of vegetation cover and leaf area index.

The fields that have relatively low yields and relatively poor vegetation condition are generally non-irrigated fields. The fact that the LANDSAT data on this date (May 21) generally is better correlated with field condition and harvested grain yield for non-irrigated fields is not really discouraging, since most of the wheat in the Great Plains is non-irrigated.

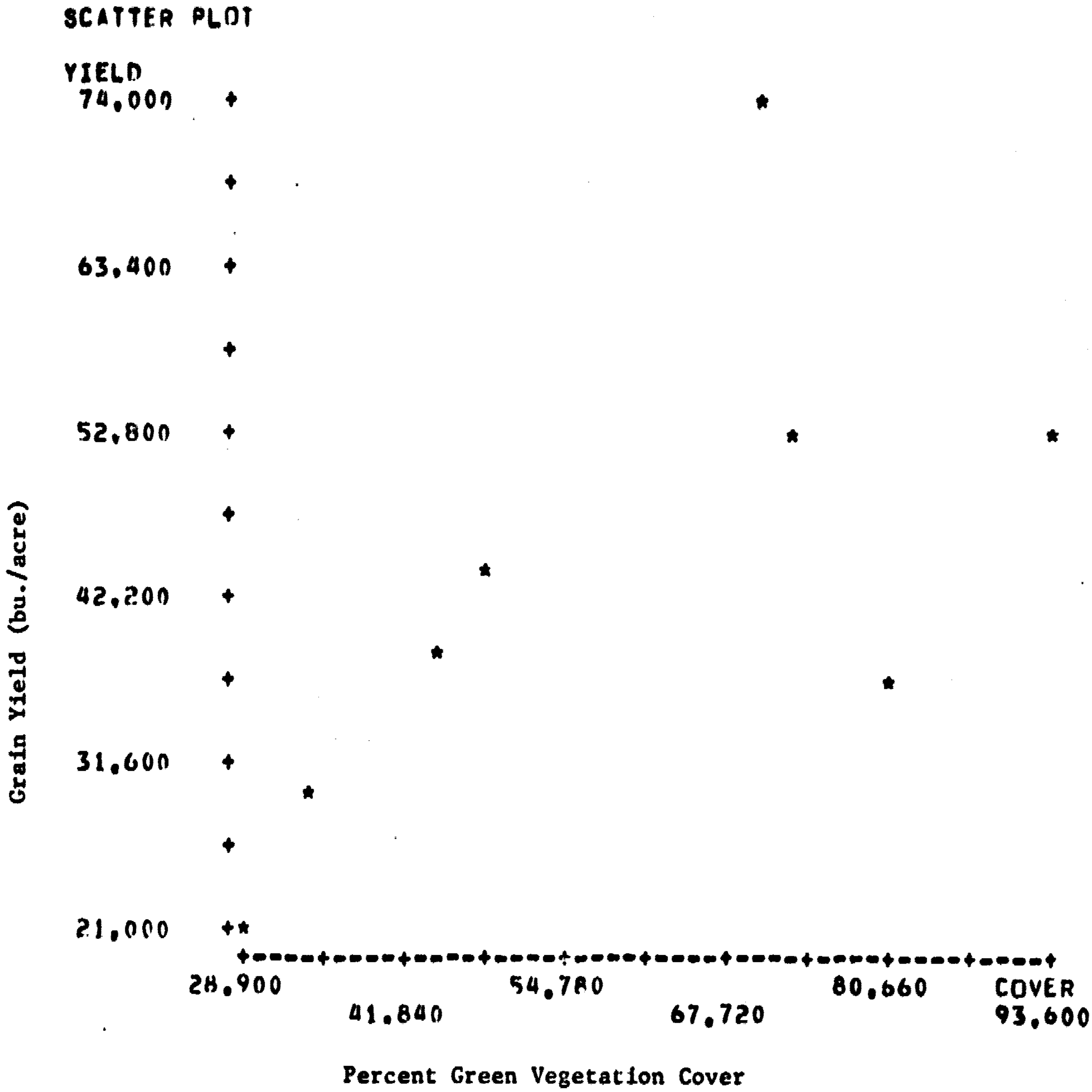

FIGURE 5. SCATTER PLOT OF HARVESTED GRAIN YIELD VS. ESTIMATES OF PERCENT GREEN VEGETATION COVER

FINNEY COUNTY SITE, 21 MAY 1975

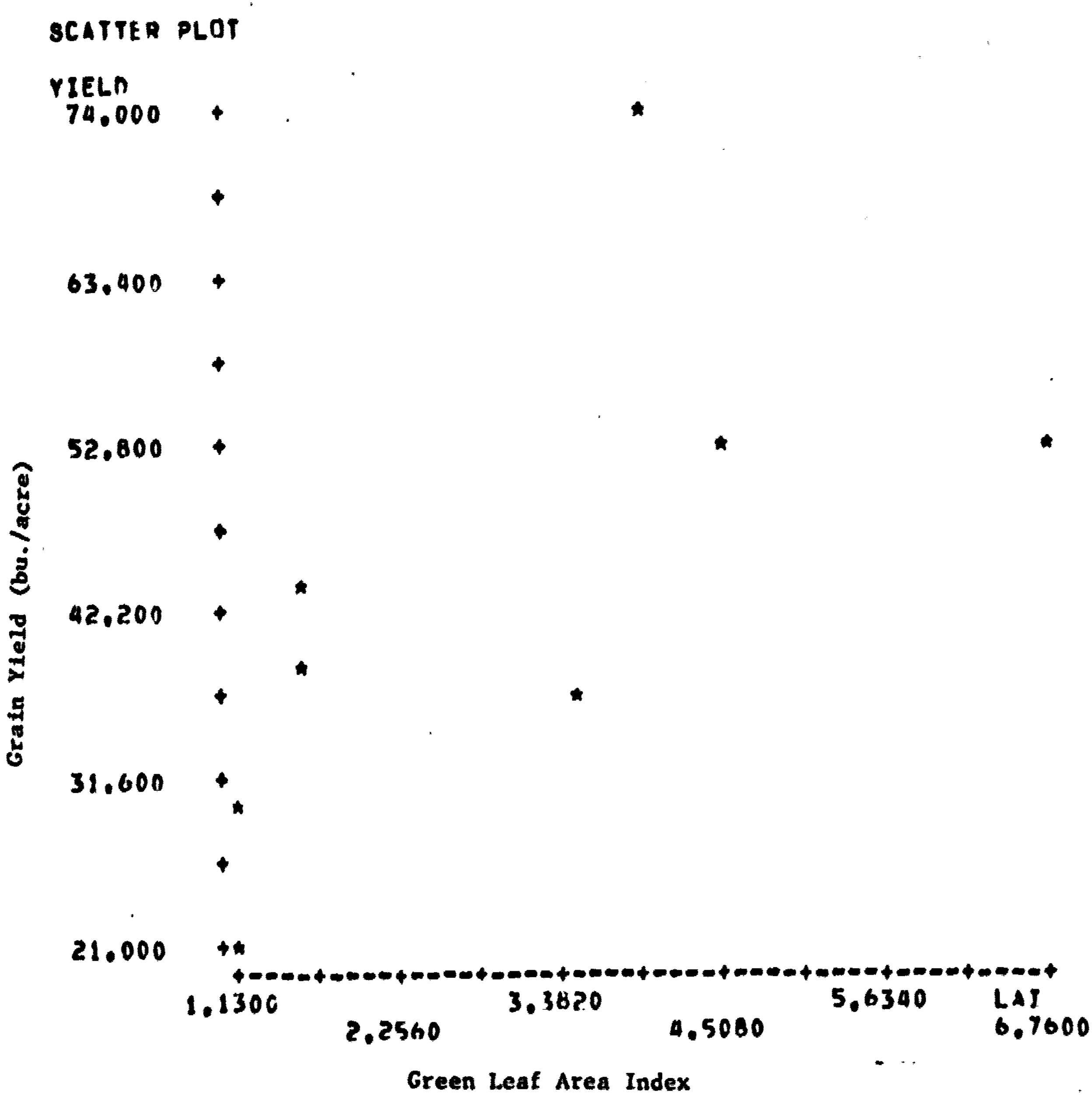

FIGURE 6. SCATTER PLOT OF HARVESTED GRAIN YIELD VS. ESTIMATES OF GREEN LEAF AREA INDEX

FINNEY COUNTY SITE, 21 MAY 1975

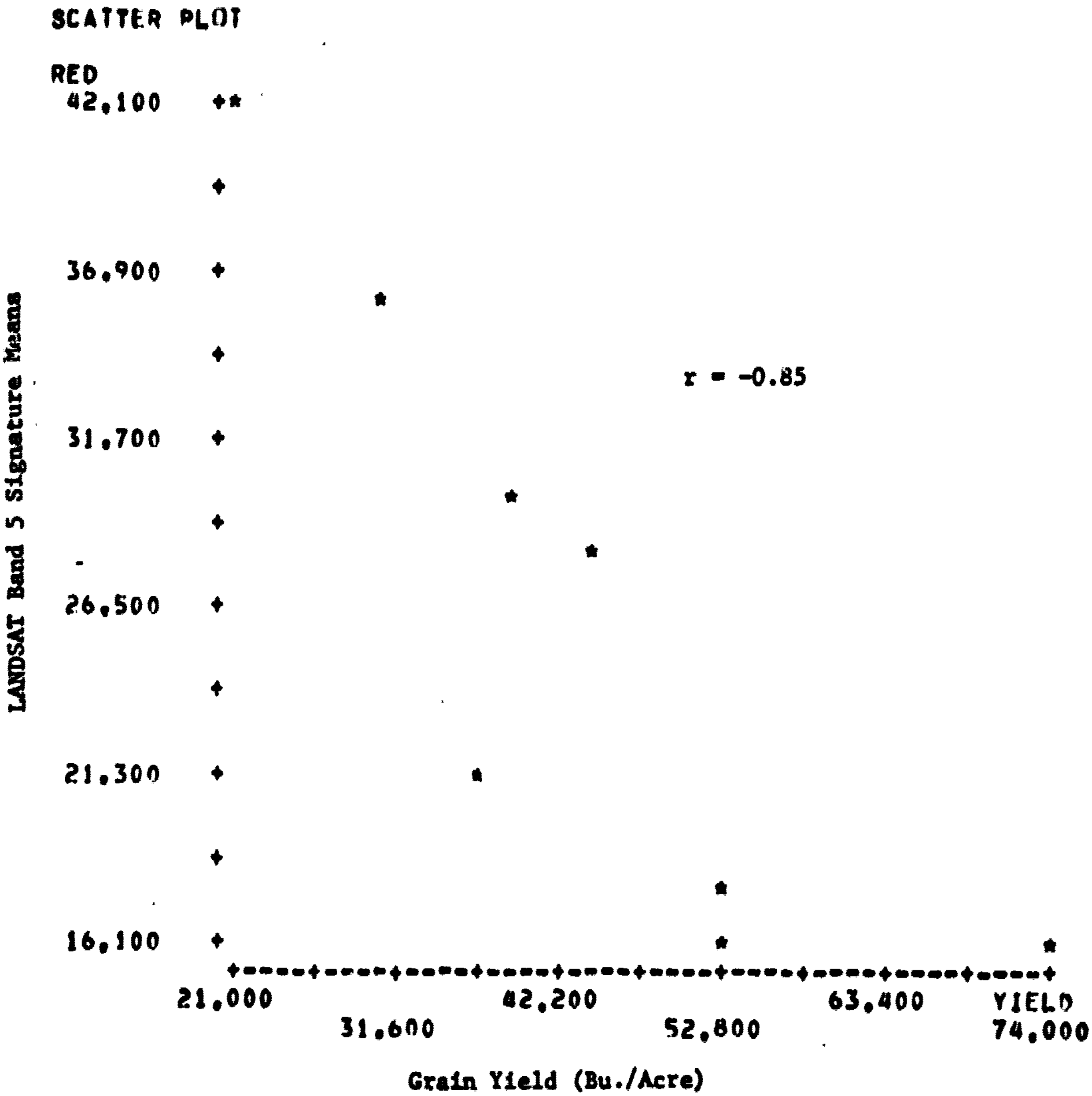

FIGURE 7. SCATTER PLOT OF LANDSAT BAND 5 VS. HARVESTED GRAIN YIELD FINNEY COUNTY SITE, 21 MAY 1975

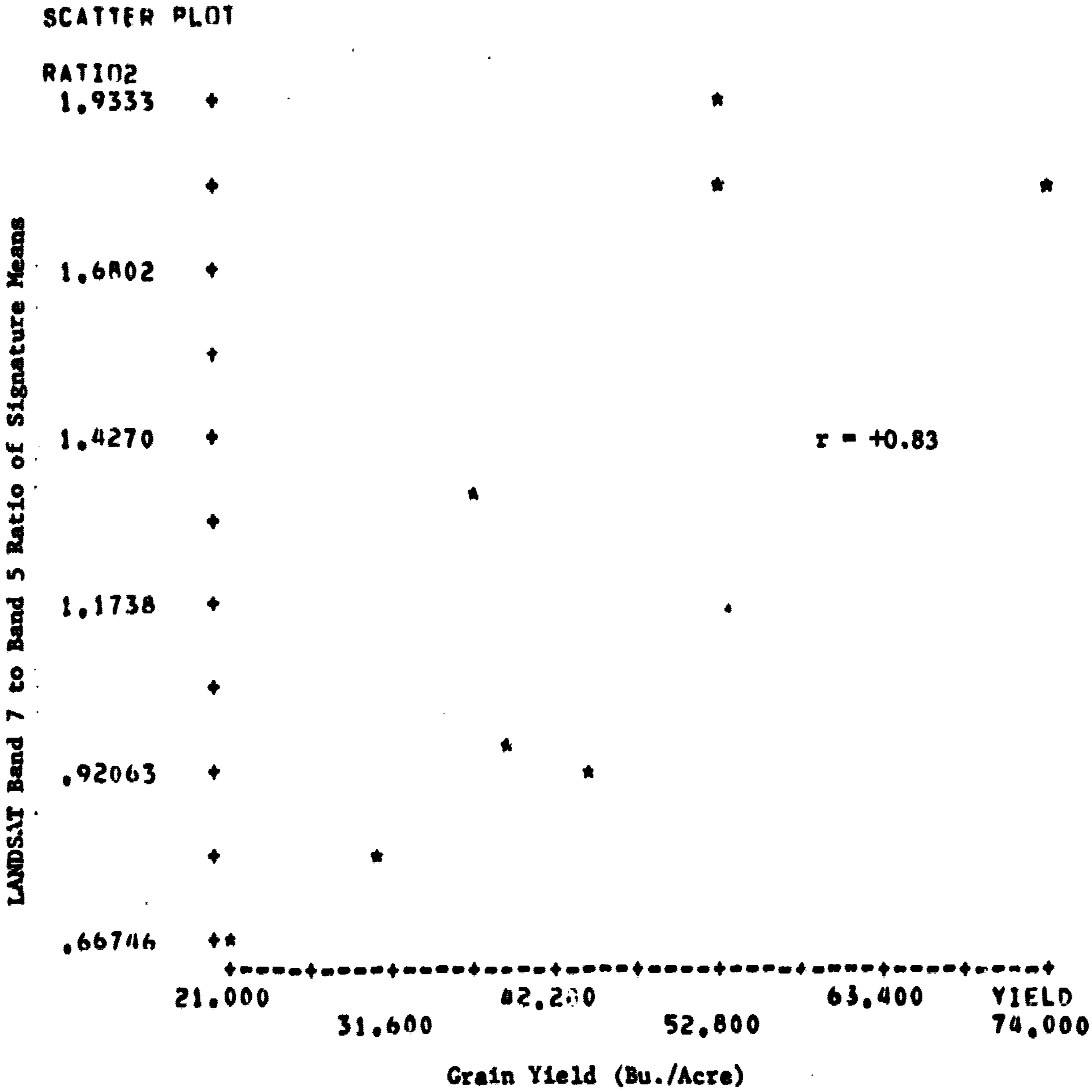

FIGURE 8. SCATTER PLOT OF RATIO OF LANDSAT BANDS 7 AND 5 VS. HARVESTED GRAIN YIELD FINNEY COUNTY SITE, 21 MAY 1975

The correlation coefficient matrices for the low vegetation cover, generally non-irrigated fields and the high vegetation cover, irrigated fields are presented separately in Tables 1 and 2. With only 4 data points for each correlation matrix, it is very risky to draw sweeping deductions. However, the data are generally consistent with our hypotheses for this project and our previous experience. Note particularly the high correlation between yield and vegetation condition (percent cover, LAI) for low vegetation cover fields (Table 1) and the insignificant correlation for the irrigated, high vegetation cover fields (Table 2).

The good correlation between LANDSAT data and grain yield for fields with low vegetation cover and low yield suggests the following possibilities which we intend to investigate:

(1) LANDSAT data may be useful for forecasting yield rather early in the growing season, even before heading (which is about the time when vegetation cover peaks).

(2) LANDSAT data may be useful for assessing fields with quite low vegetation cover and potential yield. It may therefore be possible to determine the number (and acreage) of fields which are not likely to be harvested. It is important to know this figure in order to know how much grain will actually be available for human consumption.

In addition, irrigated and non-irrigated fields appear to be generally differentiable, so alternative yield estimation techniques might be applied to the acreage identified as irrigated, if that is required. Irrigation data we have received from Finney County ASCS personnel suggests that yield on irrigated fields is correlated with the amount of irrigation.

The relationships between grain yield and the 16 wheat fields for which we were able to derive 21 May LANDSAT signatures are presented in Figures 9 and 10. Although we do not have field condition

TABLE 1. CORRELATION MATRIX FOR FOUR FIELDS WITH LOW VEGETATION COVER.

No. of Data Points: 4
No. of Degrees of Freedom: 2
Significant Correlation @
.05 Level: .95
.01 Level: .99

	VARIABLE	1. YIELD	2. LAI	3. COVER	4. GREEN	5. RED	6. IR1	7. IR2	8. RAT2
	1. YIELD	1.0000							
	2. LAI	.9889	1.0000						
	3. COVER	.9943	.9739	1.0000					
MSS 4	4. GREEN	-.9962	-.9825	-.9990	1.0000				
5	5. RED	-.9937	-.9750	-.9996	.9993	1.0000			
6	6. IR1	-.8362	-.7499	-.8437	.8269	.8401	1.0000		
7	7. IR2	.4631	.5809	.4356	-.4738	-.4488	.0985	1.0000	
7/5	8. RAT2	.9824	.9987	.9632	-.9784	-.9701	-.7199	.6181	1.0000

KEY:

1. YIELD Harvested grain yield in bu./acre.
2. LAI Leaf Area Index, from ERIM field measurements.
3. COVER Percent cover, from ERIM field measurements.
4. GREEN Signature mean in LANDSAT Band 4.
5. RED Signature mean in LANDSAT Band 5.
6. IR1 Signature mean in LANDSAT Band 6.
7. IR2 Signature mean in LANDSAT Band 7.
8. RAT2 Ratio of signature mean in Band 7 ÷ Band 5.

TABLE 2. CORRELATION MATRIX FOR FOUR FIELDS WITH HIGH VEGETATION COVER.

No. of Data Points: 4
No. of Degrees of Freedom: 2
Significant Correlation @
.05 Level: .95
.01 Level: .99

CORRELATION COEFFICIENTS

	VARIABLE								
	1.YIELD	1.0000							
	2.LAI	.0539	1.0000						
	3.COVER	-.4422	.7877	1.0000					
MSS 4	4.GREEN	-.7725	.3014	.8235	1.0000				
5	5.RED	-.8296	-.1933	.4501	.8771	1.0000			
6	6.IR1	-.2479	.9464	.9366	.5863	.1277	1.0000		
7	7.IR2	.0470	.9666	.8611	.4322	-.0448	.9474	1.0000	
7/5	8.RAT2	.5670	.7100	.1409	-.4442	-.8164	.4447	.6134	1.0000
		1. YIELD	2. LAI	3. COVER	4. GREEN	5. RED	6. IR1	7. IR2	8. RAT2

KEY: See Table 1.

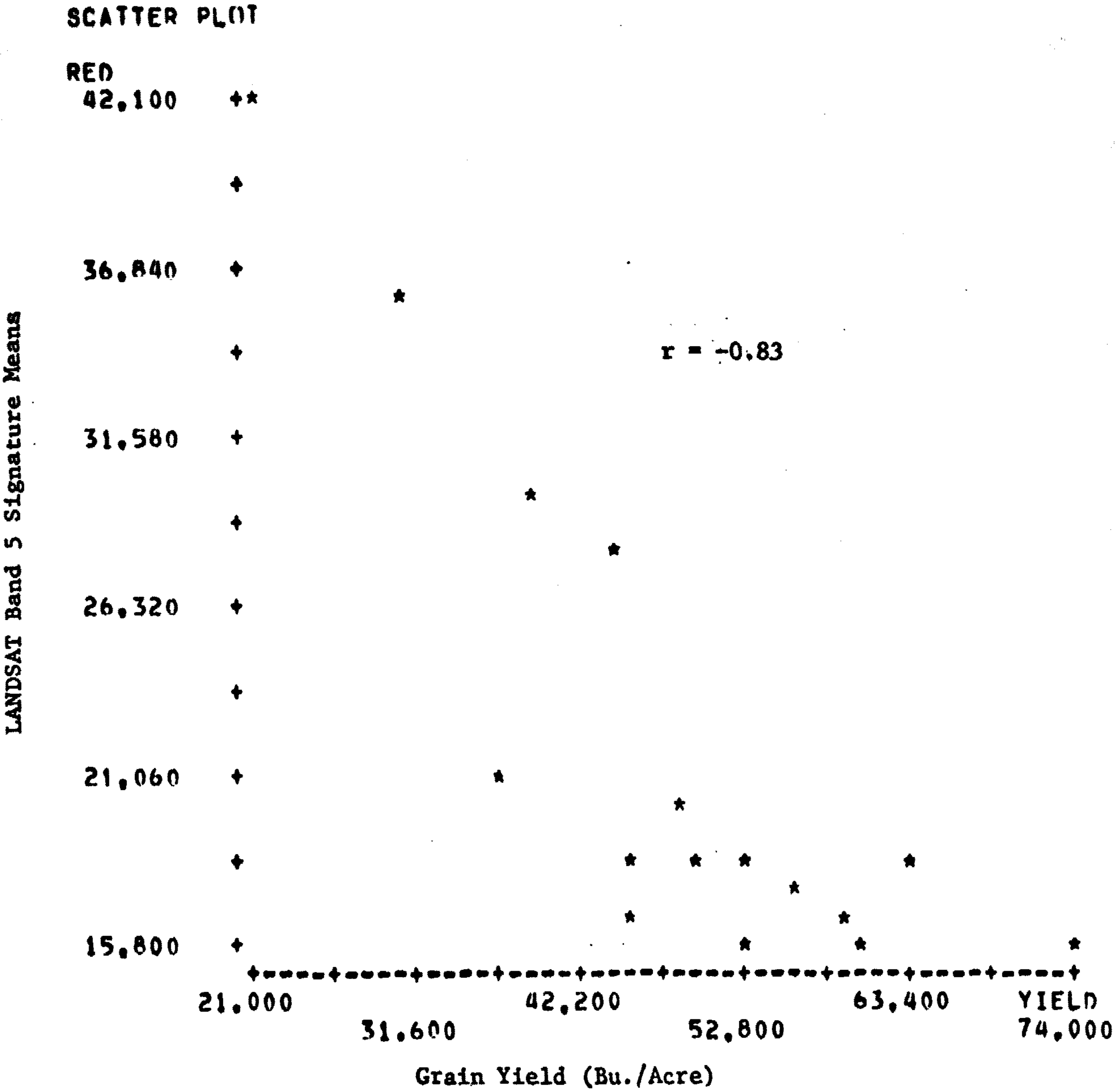

FIGURE 9. SCATTER PLOT OF LANDSAT BAND 5 VS. HARVESTED GRAIN YIELD FOR 16 FIELDS FINNEY COUNTY SITE, 21 MAY 1975

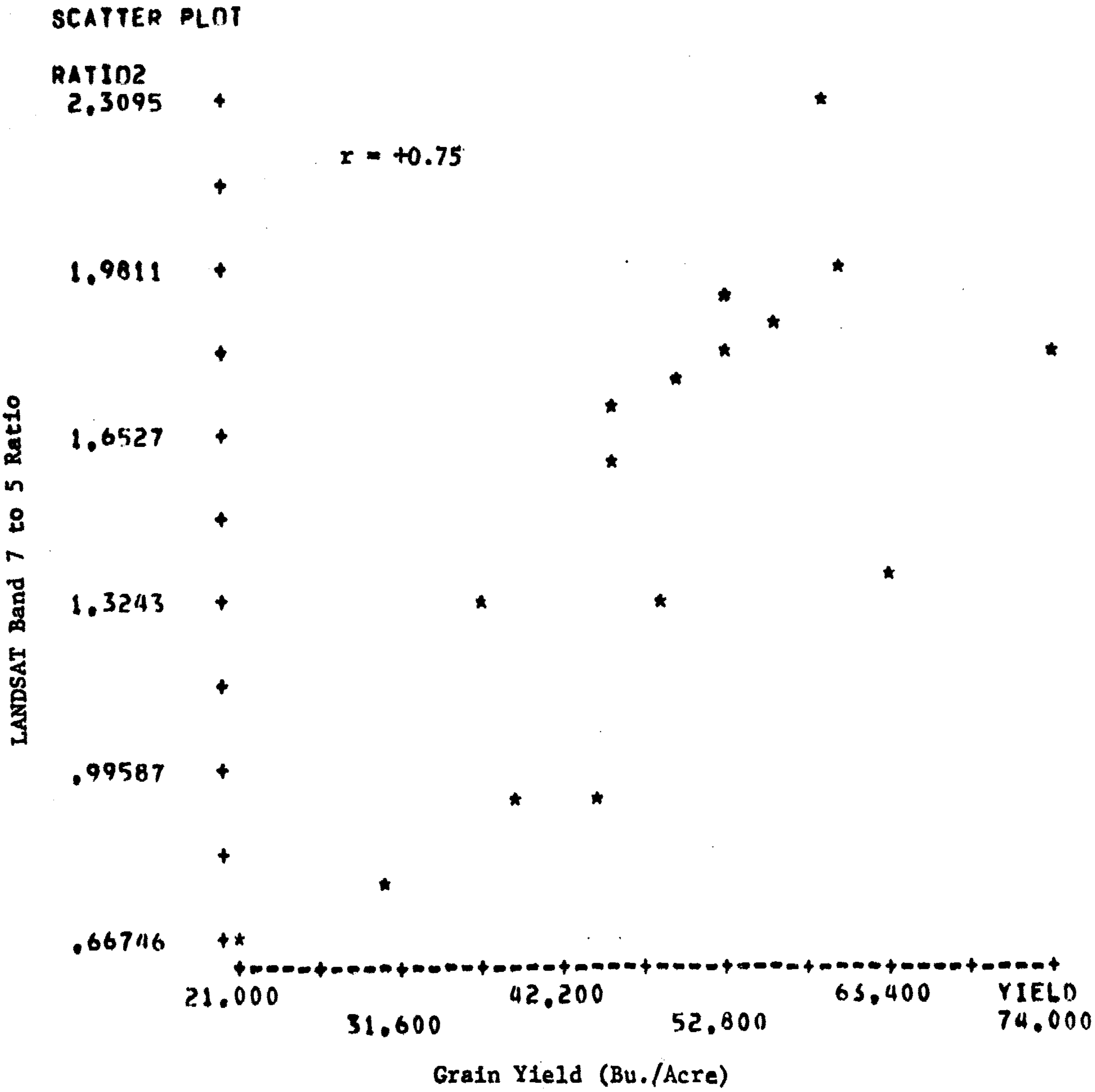

FIGURE 10. SCATTER PLOT OF LANDSAT BAND 7 TO 5 RATIO VS. HARVESTED GRAIN YIELD FOR 16 FIELDS.

FINNEY COUNTY SITE, 21 MAY 1975

on all of the fields, the relationships between LANDSAT data and yields are not inconsistent with our previous analyses.

There is some correlation between LANDSAT data and yield for the 12 irrigated/high vegetation cover fields included in Figures 9 and 10 but an algorithm relating LANDSAT data to yield is apparently different for irrigated and non-irrigated fields.

The theoretical yield modeling previously done [4] suggested that peak LAI was correlated with grain yield and that peak LAI could be estimated by use of an IR/red ratio. The data processed thus far tends to support that finding, at least for non-irrigated fields. The yield modeling also indicated a strong dependence of yield on soil moisture. The correlation between amount of irrigation and yield also supports that hypothesis.

It should be noted that the above findings are all preliminary, for a very small set of data on one date. In addition, there may be some anomalies in this data. The relationship between an IR band (particularly LANDSAT Band 6) and vegetative condition (L.A.I. and percent cover) that we observe does not match what we expect based on theoretical simulations of IR reflectance we constructed from field measurement data (radiometric properties and structure and density measurements). We are in the process of investigating the reasons for the apparent anomalies.

The timing of the observation of the vegetative condition of the crop may be important for assessing yield. This fact was suggested by our previous theoretical work [4] and is supported by Figures 11 and 12 which show the status of ERIM field measurements of vegetative cover and LAI for three fields with considerably different harvested grain yields on three LANDSAT overpass dates. For this limited set of data, it appears that the May 21 date (heading) is the best single date for finding yield differences correlated with vegetation condition (and hence LANDSAT data). However, several dates combined may

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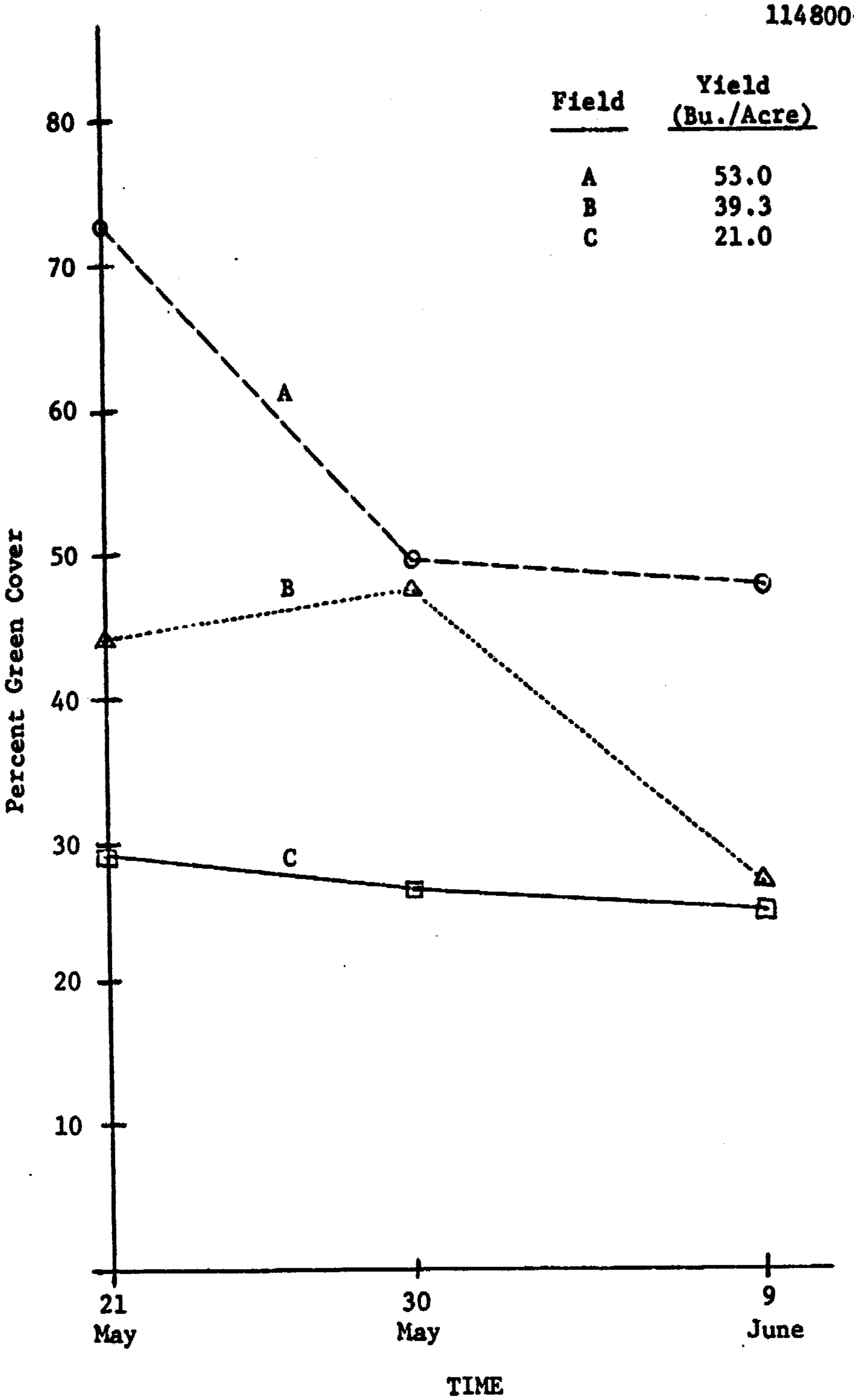

FIGURE 11. THE TREND OF ERIM FIELD MEASUREMENT OF GREEN VEGETATION COVER FOR THREE FIELDS WITH VARIOUS HARVESTED YIELDS.

FINNEY COUNTY SITE, 1975

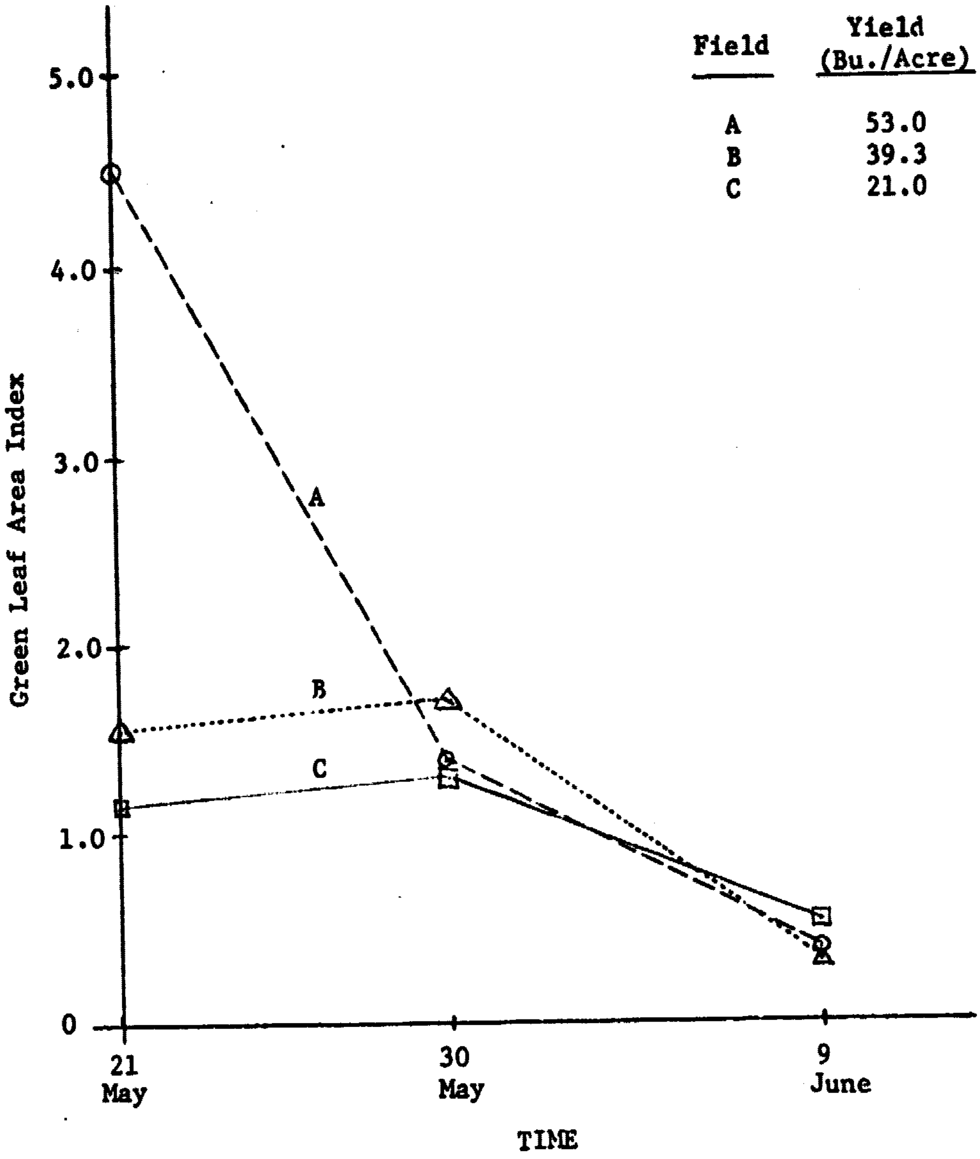

FIGURE 12. THE TREND OF ERIM FIELD MEASUREMENT OF GREEN LEAF AREA INDEX (LAI) FOR THREE FIELDS WITH VARIOUS HARVESTED YIELDS.

FINNEY COUNTY SITE, 1975

give a better indication of yield than any single date. Our previous theoretical modeling suggested that leaf area duration was highly correlated with wheat grain yield.

D. PUBLICATIONS

There were no publications or presentations during this reporting period.

E. RECOMMENDATIONS

1. Additional ground truth for the Ellis intensive test site should be obtained through Johnson Space Center.
2. The availability of the Finney, May 3, 1975 LANDSAT frame should be doublechecked through Goddard Space Flight Center.
3. Helicopter spectral reflectance data should be obtained.
4. MSDS coverage of Finney site should be obtained.

F. FUNDS EXPENDED

Total expenditures during the period 16 November 1975 through 15 February 1976 are $8,766.

G. DATA USE

	Value of Data Allowed	Value of Data Ordered	Value of Data Received
USDI EROS Data Center	$12,000	$4,000	$2,600
USDA/ASCS Aerial Photography Field Office	$ 2,000	$ 783	$ 783

REFERENCES

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2. Henderson, R. and D. Rice. 1975. "Signature Extension," Quarterly Technical Progress Report, May-August 1975, ERIM 109600-37-L, Task 15, Contract NAS9-14123.

3. Kauth, R. 1976. "Haze Correction Algorithm for PROCAMS," Appendix to the Quarterly Technical Progress Report, November 1975-February 1976, ERIM 109600-58-L, Task 15, Contract NAS9-14123.

4. Colwell, J. and G. Suits. 1975. "Yield Prediction by Analysis of Multispectral Scanner Data," ERIM Report 109600-17-F, Contract NAS9-14123.

5. Colwell, J. 1974. "Grass Canopy Bidirectional Spectral Reflectance," Proceedings of the Ninth International Symposium on Remote Sensing of Environment, Environmental Research Institute of Michigan, Ann Arbor, Mich., pp. 1061-1085.

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